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REVIEW OF THE TORTUGAS PINK SHRIMP FISHERY FROM MAY 1986 TO DECEMBER 1987

By

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INTRODUCTION

The Gulf of Mexico Shrimp Fishery Management Plan established an area commonly known as the Tortugas Shrimp Sanctuary off south Florida in May 1981 (Fig. 1). The goal of the Gulf of Mexico Fishery Management Council in establishing the Sanctuary was to protect small, undersized shrimp from being fished and to increase and optimize the overall poundage yield from the fishery. This decision was based on scientific evidence that showed the Sanctuary area to be the nursery ground for the Tortugas stock of the pink shrimp Penaeus duorarum, and that the poundage yield of offshore pink shrimp would be greater if harvest was delayed until shrimp were larger than minimum legal size in Florida (69 tails per pound) (Lindner, 1965; Berry, 1970). Since May 1981, the whole Sanctuary has been closed to trawling, with the exception of a small region locally known as the "toe area", which was reopened for a brief period (April 1983 through August 1984) to evaluate the effects (Klima and Patella, 1986).

This paper reviews the characteristics of the Tortugas fishery from May 1986 to December 1987 (biological year 1986 and part of 1987) and compares results with historical data. Deviations from historical averages are discussed in light of the established Sanctuary. Current trends with regards to the Tortugas fishery also are discussed.

METHODS

Fishery Data Statistics

Collections of detailed catch statistics describing the Gulf of Mexico shrimp fishery in United States waters since 1956 are compiled by and available from the Southeast Fisheries Center (SEFC)/Office of Economics and Statistics (ESO). The procedures used to collect them have been described by Klima (1980). These statistics consist of catch, recorded as pounds of shrimp (heads-off); fishing effort, recorded as either 24 hours of actual fishing time or number of trips; and size composition of catch,

expressed in eight "count" or size categories representing number of shrimp tails per pound (<15, 15-20, 21-25, 26-30, 31-40, 41-50, 51-67 and ≥ 68).

These statistics were grouped and analyzed by biological year (May through April) and used in this report to determine the effects of the Tortugas Shrimp Sanctuary on the fishery. These statistics were also used to calculate other useful values such as catch per unit effort (CPUE), expressed as pounds per 24 hours of actual fishing, and average number of shrimp per pound. All statistical tests utilized in the report are described in detail by Nance et al. (1986).

Pink shrimp recruitment from 1960-1986 for the eastern Gulf of Mexico was estimated using a standard VPA analysis. Procedures are outlined by Nance and Nichols (1988).

RESULTS

Landings

Annual landings by biological year, May 1960 to April 1986, in statistical subareas 1 through 3, have averaged approximately 9.8 million pounds yearly (Fig. 2). Pounds landed have fluctuated from a high of 13.4 million pounds in 1960 to a low of 6.9 million pounds in 1983. Yet, even with this 6.5 million pound range, the fishery has remained relatively stable throughout this 26 year period. The standard deviation around the historical mean was only ± 1.7 million pounds, with a value of 17% for the coefficient of variation. Only during biological years 1960, 1965, 1971, 1982 and 1983 have yearly landings fallen outside one standard deviation of the mean.

However, during biological year 1986 (May 86 - April 87), only 5.5 million pounds of pink shrimp were landed from statistical subareas 1-3 (Fig. 2). This value represents the lowest catch recorded from the area and is the first year that it is significantly below the historical average.

Estimates of pink shrimp landings during biological year 1987 are also very low in comparison to the historical average and all years since 1960,

with the exception of 1986. The estimated landings for 1987 (May 1987-April 1988) are around 6.1 million pounds, which is also significantly below the historical average. Only actual landings from May 1987-December 1987 are available on computer, but tentative figures from January 1988-April 1988 were gathered from port agents in the area. Only landings were estimated, so statistics such as effort, CPUE, and size composition will only be reported for the first eight months of biological year 1987.

The monthly pattern of shrimp landings in biological year 1985 (May 85 - April 86) when compared with historical monthly averages showed that most catches during the summer and fall were similar to or slightly above the historical average for the month (Nance and Patella, 1987). All winter months (October-February) showed below average values, but none were significantly different from their respective historical average. Landings during the early spring months (March and April) were near the average value recorded for those months.

Yet, when the monthly pattern of shrimp landings in biological years 1986 and 1987 were compared with historical monthly averages, a dramatic decrease in pounds landed was noted (Fig. 3). Even though all months except four were below average, only five months were significantly below their respective historical average. The significantly below average months occurred in the early winter months (October-December) in biological year 1986 and during the late winter months (February-March) in biological year 1987. It appears that the shrimp were late in arriving onto the fishing grounds in biological year 1986 and when they did arrive they were in greatly reduced numbers (Fig. 4). In biological year 1987 the shrimp seemed to be present on the grounds in the early winter, but at a level that was quickly reduced by fishing (Fig. 4).

Fishing Effort

Fishing effort by biological year, May 1960 to April 1985, in statistical subareas 1 through 3 has averaged 16,000 days per year with a standard deviation of $\pm 2,300$ days per year (Fig. 5). The coefficient of variation was 14%. The small standard deviation and low coefficient of variation are

good indicators of the stability of this fishery. Even so, effort has fluctuated from a high of 22,000 days expended in 1960 to a low of only 11,000 days fished in 1979.

Fishing effort reported for biological year 1986 was around 12,600 days, which is below average, but only slightly below one standard deviation of the historical mean. Only four other years, 1976, 1979, 1981 and 1985 have also been below the one standard deviation from the mean level.

The monthly pattern of fishing effort in biological year 1986 and the first 8 months of biological year 1987 were compared with historical monthly averages (Fig. 6). Below average fishing effort values were noted during most of the months of biological year 1986. Yet, during most of the months that comprise biological year 1987, above average effort was experienced on the Tortugas grounds. Effort data is not yet available for the January 1988-April 1988 period, but since reported catches dropped off significantly during this period it is assumed that effort levels also dropped below their historical values.

Relative Abundance

The relative abundance of pink shrimp, as expressed by catch per unit effort (CPUE), is reported as pounds caught during a 24 hour fishing day (pounds per day). The annual CPUE at the Tortugas fishing grounds has been a very stable parameter over the past 26 years. CPUE values have averaged about 610 pounds per day with a standard deviation of around 87 pounds per day (Fig. 7). This has resulted in a coefficient of variation value of only 14%. The highest historical CPUE recorded was close to 800 pounds per day during biological year 1981 and the lowest CPUE was 505 pounds per day, which occurred during biological years 1982 and 1983. The annual CPUE value during biological year 1986 was below average at only 436 pounds per day. This value is the lowest CPUE value ever recorded from this fishery and was significantly different from the historical mean.

Even though annual CPUE values for the past 27 years have not varied considerably (with the exception of 1986), large variations have been noted

in monthly CPUE values (Nance and Patella, 1987). Thus, a large standard deviation value is found around each monthly historical mean CPUE value. Monthly CPUE values for biological year 1986 and the first 8 months of biological year 1987 were compared with their respective monthly historical mean value (Fig. 8). All months, except June 1986 and June 1987 had below average CPUE values when compared with their historical average. This was expected, since landings were below average during the period, but effort was only slightly below historical levels.

In comparing the the monthly CPUE values with the historical data, we also plotted a ratio of the monthly CPUE values from May 1981 through December 1987 over the historical monthly CPUE values (Fig. 9). These values indicated that for the 3 months of greatest catch (December, January and February) that the biological year 1986 winter values (December 1986-February 1987) were very similar to winter values in biological years 1982 and 1983, but were below winter values in biological years 1981, 1984 and 1985. However, biological year 1986 (May 1986-April 1987) was set apart from all other years by the fact that all months, except one, were below the equality line. Similar results are seen for the first 8 months of biological year 1987.

Recruitment

Total pink shrimp recruitment has been quite stable over the past 27 years, with a mean value of 1.6 billion shrimp (Fig. 10). Recruitment has ranged from a high of 2.5 billion shrimp experienced in biological year 1980 to a low of 1.2 billion shrimp in biological year 1986. The total pink shrimp recruitment during a given biological year is highly correlated (0.93) to total pink shrimp catch during the same period. Regression analysis, with total catch as the dependent variable and total pink shrimp recruitment as the independent variable, gave an r-squared value of 0.86. Thus, as one would expect, the amount of catch experienced from the pink shrimp fishery in a given year, is a direct result of the strength of the recruitment of pink shrimp during the same period. If recruitment is low, catch will be low. If recruitment is high, catch will be high.

Recruitment of pink shrimp onto the Tortugas grounds usually occurs during two periods in a biological year. Fall recruitment is measured from July through December, with the peak of the season from August through October. The spring season is measured from January through June, with peak recruitment usually from March through May (Fig. 11). Fall recruitment has averaged 820 million shrimp per season since 1960, with a slight downward trend; except 1984 and 1985, beginning in 1981. Spring recruitment has averaged 800 million shrimp per season since 1960, and with the exception of four seasons has been above average since 1977.

Total catch on the Tortugas grounds for a given biological year has a high correlation to fall season recruitment (0.72) and low correlation to spring season recruitment (0.21). This is apparent in Figure 12. Note that for most seasons, when fall recruitment rises from one year to the next, catch also rises. When fall recruitment drops, a decrease is usually seen in the catch for that biological year. Regression analysis conducted with Tortugas catch and fall recruitment gave a r-squared value of 0.52.

Biological year 1986 had both the lowest total recruitment (1.16 billion shrimp) and the lowest fall recruitment (.530 billion shrimp) on record. Thus, it is not surprising that this year also had the lowest annual catch ever recorded. Fall recruitment during biological year 1987 (July 87 -December 1987) was only .727 billion shrimp, so it appears that 1987 should also be below normal with regards to catch.

Size

The size of shrimp landed may be used to identify change that may have occurred due to fishing. If the management measure of prohibiting trawling in the sanctuary was effective and restricted the capture of small shrimp, one would expect the size of shrimp to increase and therefore be different than the historical average sizes. From April 1983 through August 1984, when part of the Tortugas Sanctuary (the toe area) was opened to fishing for comparative purposes, many small shrimp were caught (Table 1). Once this area was closed again, mean number of shrimp per pound decreased abruptly. Thus, small shrimp (50-60 count) were caught in great abundance

during that open period, while larger sized shrimp (35-45 count) have been caught thereafter with the exception of this last season (Fig. 13). During the entire calendar year of 1987, except July and August, smaller than average shrimp were landed from the fishery.

DISCUSSION

The Tortugas fishery has been quite stable over a 26 year period (1960-1985). Evaluation of annual historical data showed very low coefficient of variation values for landings (17%), fishing effort (14%), and CPUE (14%). The fishery is bounded naturally by untrawlable bottoms of loggerhead sponges and coral reefs where pink shrimp are protected from trawling activities, even though they may be present in high concentrations. This large area of untrawlable bottom surrounding the fishery grounds may be one reason why this fishery has been so stable since 1960. Yet, even with this noted stability a reduction in catch and CPUE has been noticed since 1982, with the exclusion of 1984 and 1985 (Fig. 2). Biological year 1986 was no exception to this downward trend.

During biological year 1986, all fishery indices (pounds landed, effort and CPUE) were below their respective historical averages. Pounds of shrimp landed were only 5.5 million pounds, with a fishing effort value of about 12,600 days. This computed to an extremely low CPUE value of only 436 pounds per fishing day. Both pounds landed and CPUE were significantly different than their historical averages.

The offshore pink shrimp fishery discussed thus far is directly dependent on young shrimp migrating in large numbers from nursery areas onto the fishing grounds. If these small shrimp are caught early, maximum yield in the fishery is not attained. Yet, if recruitment is depressed, landings will also be depressed, since the Sanctuary can only maximize the yield of the shrimp that are available to the fishery. Of the two recruitment intervals, the fall recruitment period seems to be the one that is best correlated to total annual catch. When fall recruitment is above average, annual catch is also usually above average and when fall recruitment is

low, annual catch is usually lower than average. Since 1980, fall recruitment has shown a downward slope with the exceptions of 1984 and 1985 (Fig. 11). Thus, the lower than average landings during most of that six year period seem to be related to a failure of recruitment of pink shrimp from nursery areas. In 1986 the recruitment in both the fall and spring periods was below average (Fig. 11). Periods of low recruitment were also observed in the late 1960's and 1970's (Fig. 10). Thus, this present condition is not the first time low recruitment has been observed in the fishery.

There needs to be a concerted effort by biologists to establish the reasons for the reduced recruitment of pink shrimp from the nursery areas, since this is the only way to increase the landings from the Tortugas area. A step in this direction was taken by NMFS last year. Sheridan¹ developed a model using environmental data (e.g., water levels in south Florida wells, mean October water temperature, etc.) that seems to accurately predict landings of pink shrimp for the coming year ($r^2 = 0.84$). Using this model, the lower than average landings in biological year 1986 were projected. Yet, the model predicted an average year with regards to landings for biological year 1987. This does not seem to be the case. However, hurricane Floyd moved through the south Florida area in the fall of 1987 and may have caused enough change in the environment, after the forecast was made, to alter the catches for the coming year. It is probably this changeable environment which impacts the recruitment for the next year.

Discovery of the environmental and/or man-induced factors that impact recruitment will not be an easy problem. Besides the possibility that this low level of recruitment is a naturally occurring event, two environmental and one fishery related condition, that could be impacting recruitment quickly comes to mind. Over the past few years, spraying in and around the Everglades area for mosquito control may have increased. During this same period, water may have been diverted from the Everglade area with more

¹ Personal communication. NOAA/NMFS/SEFC/Galveston Laboratory, 4700 Avenue U, Galveston, TX 77551.

intensity for use in Miami, Florida. Although there is not an established link with regards to low recruitment and these possible environmental changes, it is worth an investigation.

In many fisheries, recruitment over fishing is a major cause of the reduced recruitment condition. Yet, there was no apparent established link between pink shrimp parent stocks and recruitment in the stock assessment analysis (Nance and Nichols, 1988). Thus, recruitment over fishing does not appear to be a likely candidate for the cause of the drop in recruitment.

The permanent closure of the Tortugas Sanctuary was established in May 1981 to prevent the capture of small shrimp. As stated earlier, the whole sanctuary has been closed to trawling since that time, with the exception of the "toe area", which was reopened for a brief period (April 1983 through August 1984) to evaluate the effects. A report by Klima and Patella (1986) showed an increase in number of small shrimp caught during the period the "toe area" was opened. With the reclosure of the entire Sanctuary to shrimping activities, size ratio values (average monthly size divided by historical monthly size) again decreased. Small shrimp being recruited to the offshore fishery were rapidly harvested when the "toe area" was opened, but small shrimp were able to increase in size and then enter the fishery when the "toe area" was closed (Table 1). However, since January 1987, smaller than average shrimp have been landed from the fishery even when the entire Sanctuary was closed.

It must be assumed that these smaller than average sized shrimp were obtained from the fishing grounds and not from vessels fishing inside the Sanctuary, since violations in the closed area were at very low levels this past year (NMFS Enforcement Division)². Shrimp distribution patterns may have shifted this past year in response to environmental changes (e.g., reduced rainfall, higher water temperature, hurricane Floyd, etc.), but we have no data to support this theory. It is not known whether small shrimp

² Personal communication, Southeast Regional Office, Law Enforcement Group, 9450 Koger Blvd., St. Petersburg, FL 33702.

will continue to be found outside the sanctuary in large numbers, or if distribution patterns will return to patterns that occurred in the early 1980's. However, if this condition persists, maximum yield from the fishery will not be obtained.

The major objectives of the Tortugas closure are to 1) increase the yield per recruit, and 2) eliminate discarding of undersized shrimp. It is difficult to conclude that the Tortugas closure has met the objectives of the Gulf of Mexico Shrimp Fishery Management Plan this year. We have no data to support or reject discarding of undersized shrimp. Since catch rates were so low this year, it is assumed that most shrimp caught, no matter the size, were landed this year. This may account for the increase in smaller than average sized shrimp being landed this past year (January 1987 - present).

Yield per recruit was certainly lower this past season because of the small size of the shrimp landed. It is not known why these shrimp were available on the grounds this past season and if they will continue to be distributed on the grounds in the future.

SUMMARY

1. Commercial pink shrimp landings from the Tortugas fishery (statistical subareas 1 through 3) have been relatively stable for the past 26 years (1960-1985). Average catch has been 9.8 million pounds per year with a standard deviation of ± 1.7 million pounds per year. Yet, pink shrimp landings during biological year 1986 were only about 5.5 million pounds. It is projected that landings will only be around 6.1 million pounds during biological year 1987. Both values are significantly different than the historical mean.
2. Fishing effort for pink shrimp on the Tortugas grounds have averaged 16,000 days annually for the past 26 years with a standard deviation of $\pm 2,300$ days. During biological year 1986, 12,600 days of fishing were expended on the Tortugas fishery. This is below the historical

average, but not significantly different. Biological year 1987 effort values appear at present to be greater than those during 1986.

3. CPUE (pounds per day fishing) has been the most stable parameter over the 26 year period, from 1960-1985, at the Tortugas fishing area. the historical average has been around 610 pounds per day with a standard deviation of only ± 87 pounds per day. However, the CPUE value for biological year 1986 was only 436 pounds per day. This value is the lowest ever experienced on the grounds and is significantly different than the historical mean. Biological year 1987 values also appear below the historical average for the area.
4. Recruitment of small pink shrimp from the nursery areas onto the grounds was very low for biological year 1986 and again for 1987. Fall recruitment was 0.53 billion shrimp in 1986 and 0.73 billion shrimp in 1987. It is this reduction in available shrimp that has reduced the catch from the Tortugas fishery. Yet, periods of low recruitment were also observed in the late 1960's and 1970's, so this present condition is not the first time low recruitment has been observed in the fishery.

Some possible reasons for the reduction in recruitment were addressed in the paper. These included the possibility of increased spraying in the Everglades for mosquito control, the increased usage of water from the Everglades by Miami, Florida and the unlikely condition of recruitment overfishing.

5. Larger than average shrimp were landed from the Tortugas grounds during the early part of biological year 1986 (May 1986 - December 1986), but smaller than average shrimp have been taken for most months since January 1987. This trend of taking small shrimp will impact the maximization of yield if it continues in the future. It is not known why the distribution pattern of the small shrimp shifted during this time period.

6. The major objectives of the Tortugas closure are to 1) increase the yield per recruit, and 2) eliminate discarding of undersized shrimp. It is difficult to conclude that the Tortugas closure has met the objectives of the Gulf of Mexico Shrimp Fishery Management Plan this year. We have no data to support or reject discarding of undersized shrimp. Since catch rates were so low this year, it is assumed that most shrimp caught, no matter the size, were landed this year. This may account for the increase in smaller than average sized shrimp being landed this past year (January 1987 - present).

Yield per recruit was certainly lower this past season because of the small size of the shrimp landed. It is not known why these shrimp were available on the grounds this past season and if they will continue to be distributed on the grounds in the future.

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Table 1. Monthly average weighted number of pink shrimp per pound for 1960-79, 1981, 1982, 1983, 1984, 1985, 1986 and 1987 (+ indicates larger size group and - indicates smaller size group than historical average; bracketed portion indicates open fishing in toe of the boot).

Months	1960-1979		1981	1982	1983
	Average Number/lb	Standard Deviation	Average Number/lb	Average Number/lb	Average Number/lb
May	46.8	5.1	57.4 +	48.4 +	56.8 +
June	45.2	4.5	52.7 +	45.7 +	50.2 +
July	44.0	4.7	44.2 +	36.6 -	58.0 +
August	44.0	7.7	38.9 -	55.0 +	49.6 +
September	48.7	7.9	47.5 -	49.0 +	44.2 -
October	47.9	4.8	41.4 -	43.3 -	44.0 -
November	43.1	3.3	36.4 -	41.3 -	36.6 -
December	40.2	2.8	34.9 -	39.3 -	36.1 -
January	40.2	3.1	35.6 -	43.6 +	49.4 +
February	42.7	3.1	42.1 -	48.0 +	48.1 +
March	47.5	4.4	46.8 -	57.5 +	58.7 +
April	48.3	5.8	49.8 +	54.1 +	60.5 +
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Months	1984	1985	1986	1987	
	Average Number/lb	Average Number/lb	Average Number/lb	Average Number/lb	
May	55.9 +	42.4 -	38.9 -	49.4 +	
June	53.1 +	42.1 -	45.3 +	56.8 +	
July	55.0 +	42.1 -	42.0 -	43.1 -	
August	46.9 +	33.5 -	39.4 -	40.1 -	
September	36.9 -	55.3 +	40.2 -	51.2 +	
October	45.8 -	45.9 -	38.9 -	58.4 +	
November	41.0 -	33.0 -	43.0 -	45.4 -	
December	35.2 -	35.6 -	39.0 -	41.8 +	
January	38.0 -	37.3 -	42.9 +		
February	39.8 -	40.1 -	46.3 +		
March	40.5 -	51.1 +	54.5 +		
April	44.2 -	48.4 +	55.6 +		

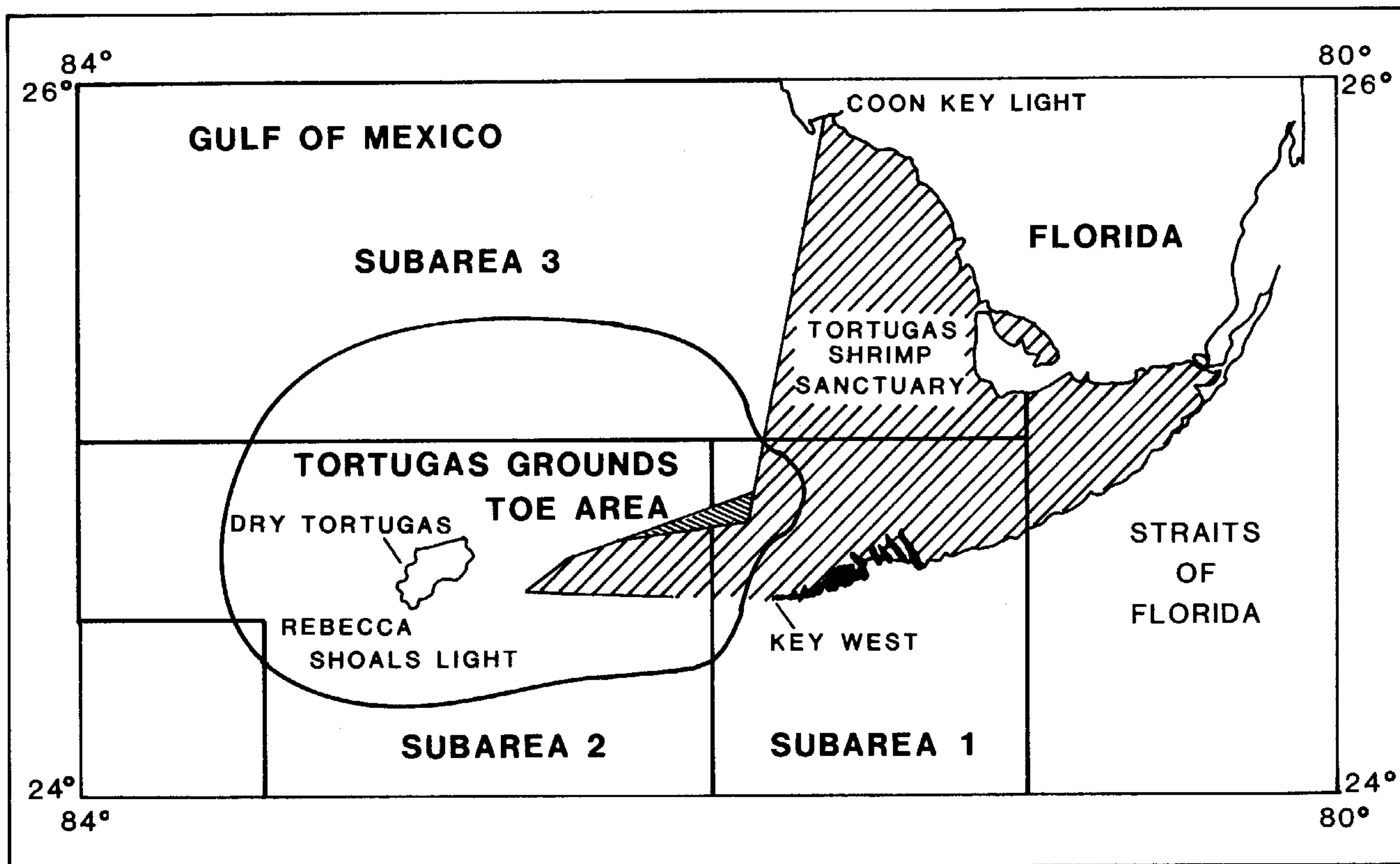


Figure 1. Map of the Tortugas fishing grounds and statistical subareas.

ANNUAL CATCH

SUBAREAS 1 - 3

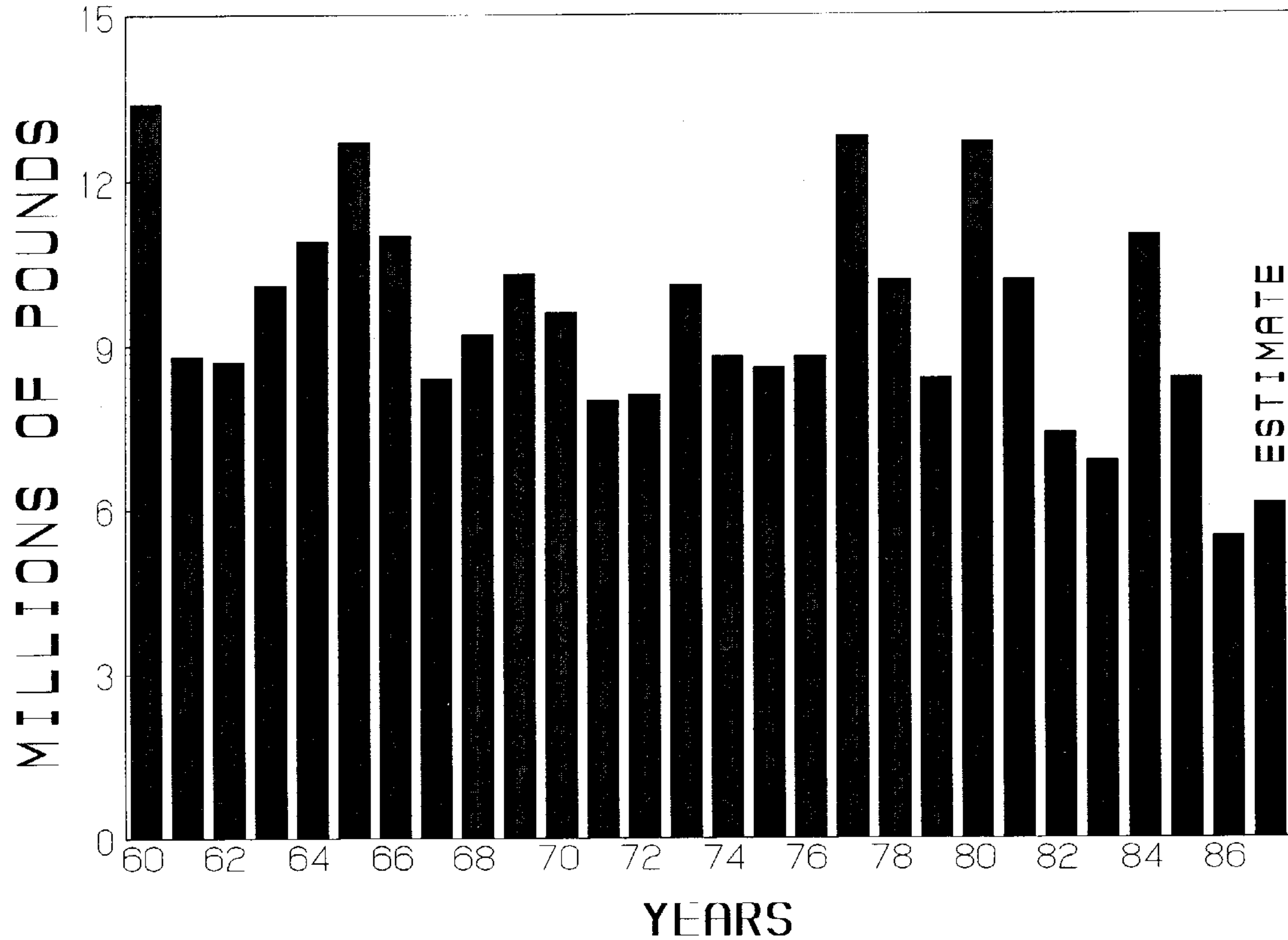


Figure 2. Annual pink shrimp landings from the Tortugas grounds for biological years 1960 through 1987.

MONTHLY CATCH

SUBAREAS 1 - 3

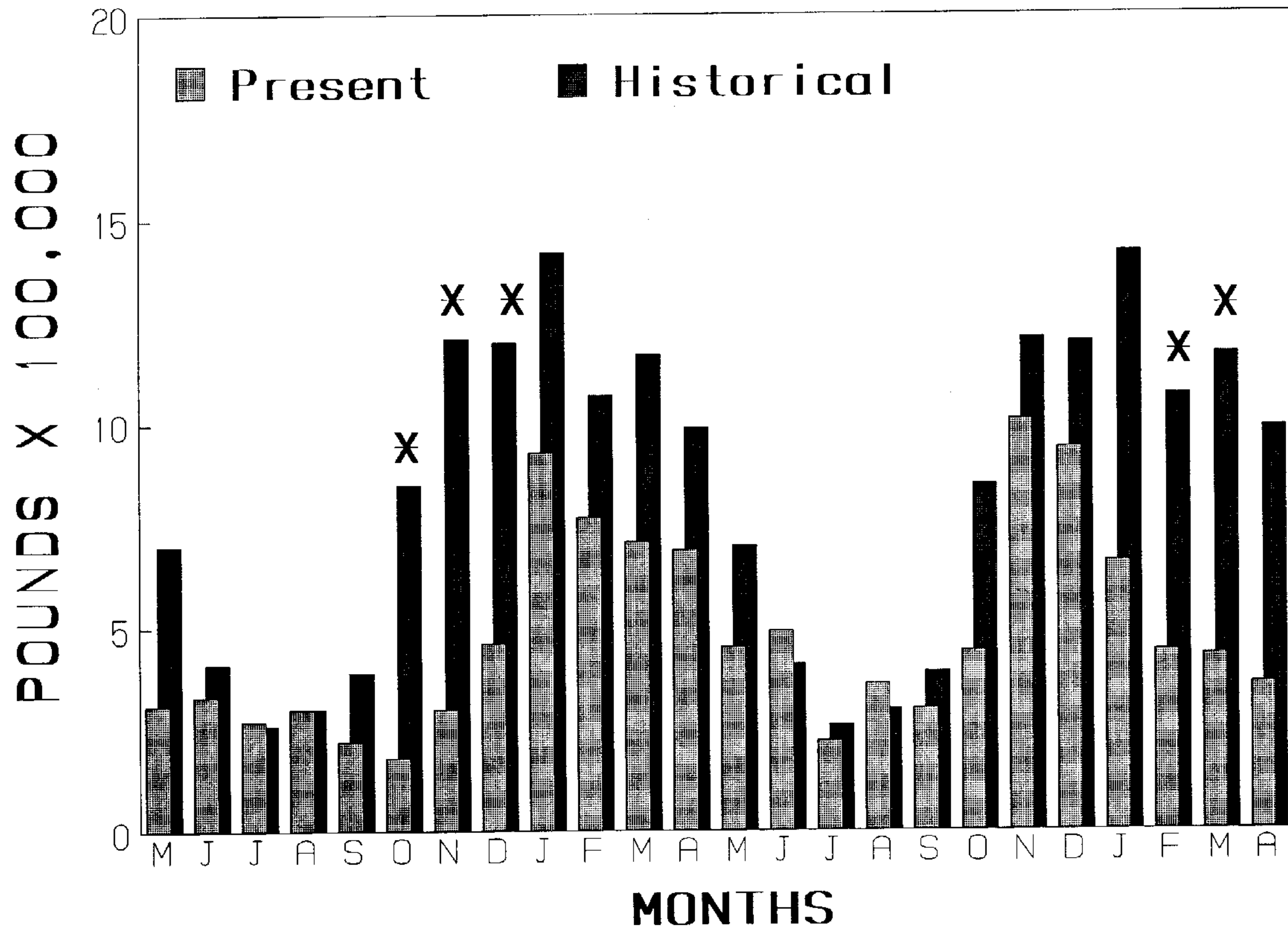


Figure 3. Average monthly historical catch compared to the catch from May 1986 through December 1987 taken on the Tortugas grounds.

ANNUAL PINK SHRIMP EFFORT

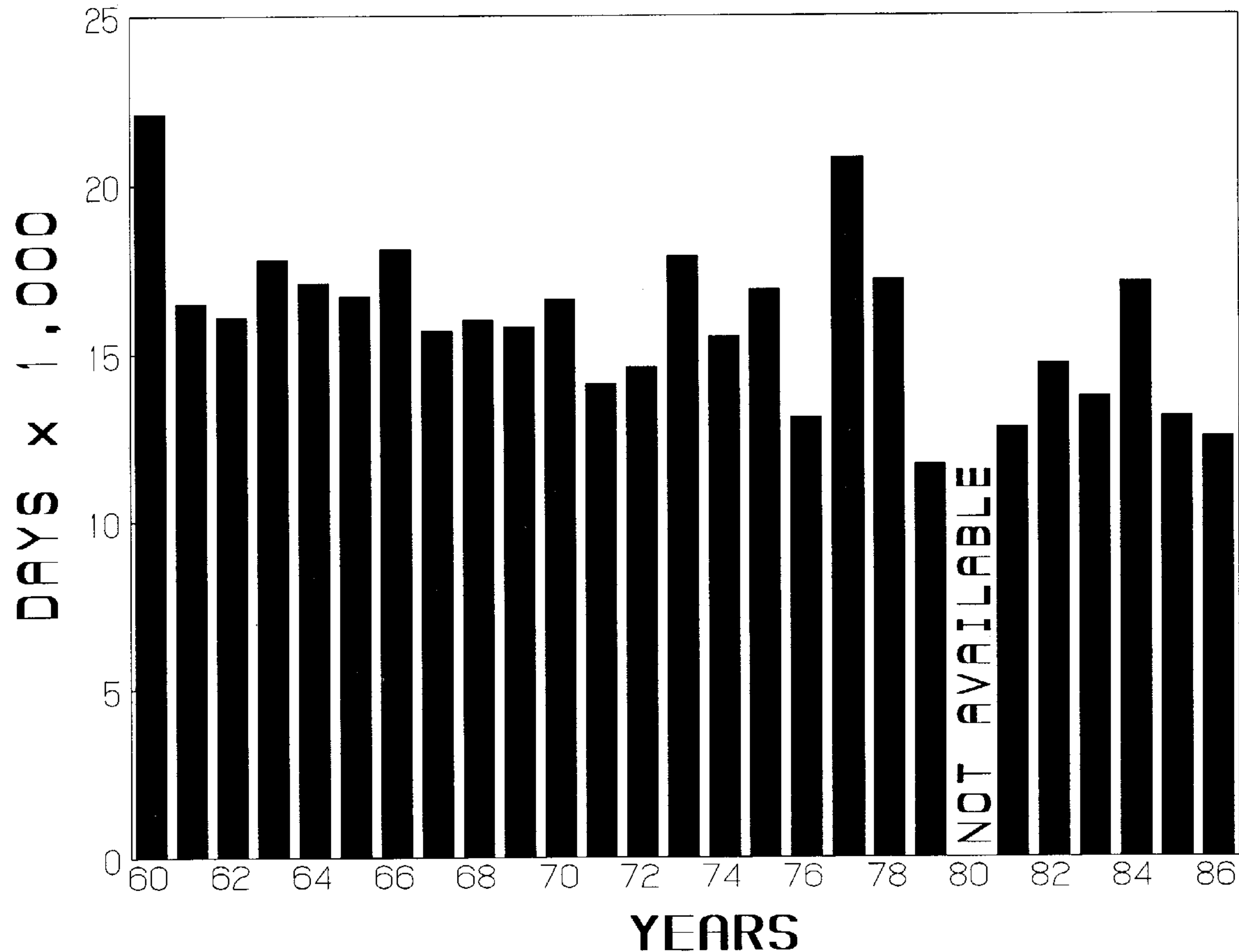


Figure 4. Pink shrimp fishery effort on the Tortugas grounds for biological years 1960 through 1986.

PINK SHRIMP TOTAL EFFORT

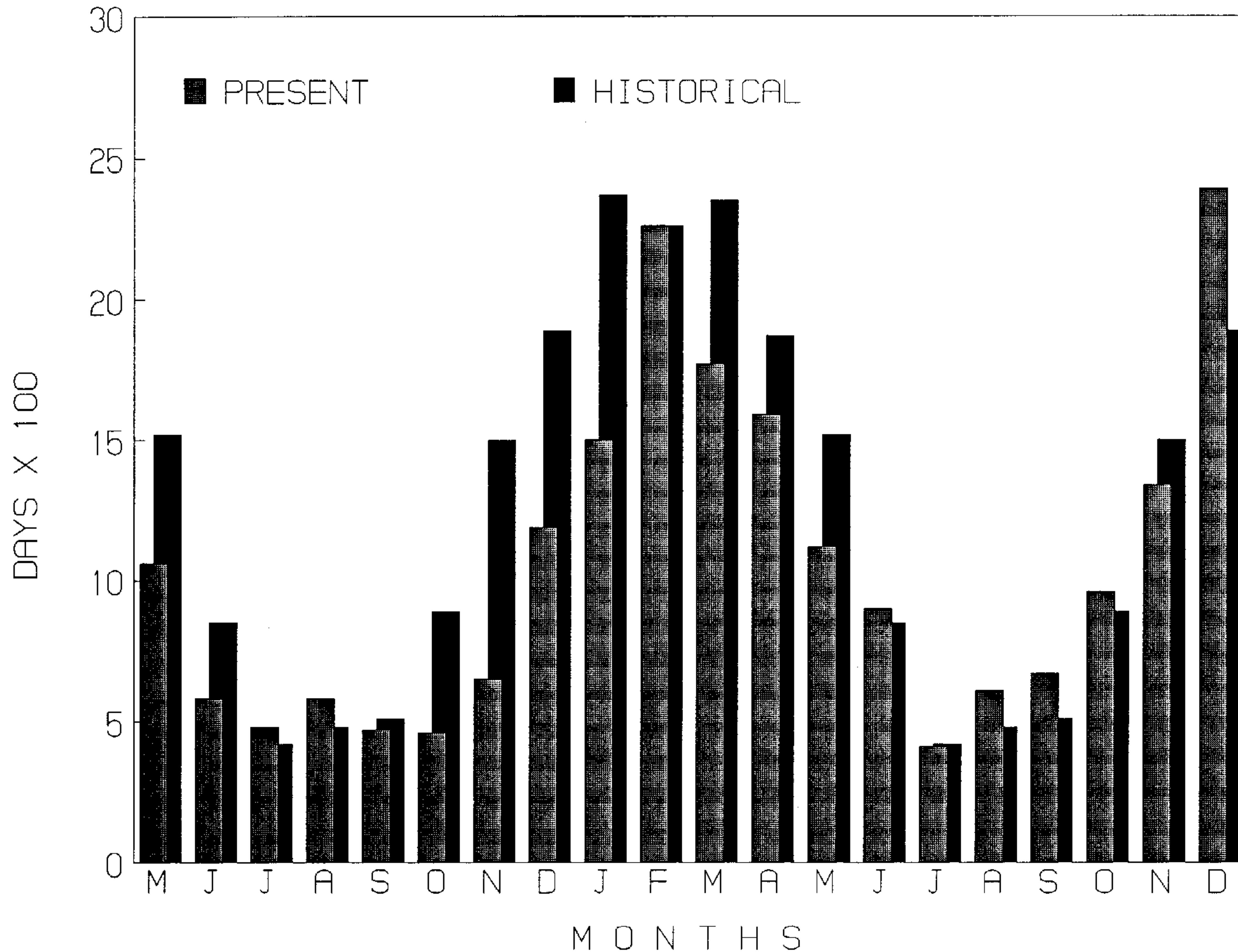


Figure 5. Average monthly historical effort compared to the monthly efforts for May 1986 through December 1987 from the Tortugas grounds.

ANNUAL PINK SHRIMP CPUE

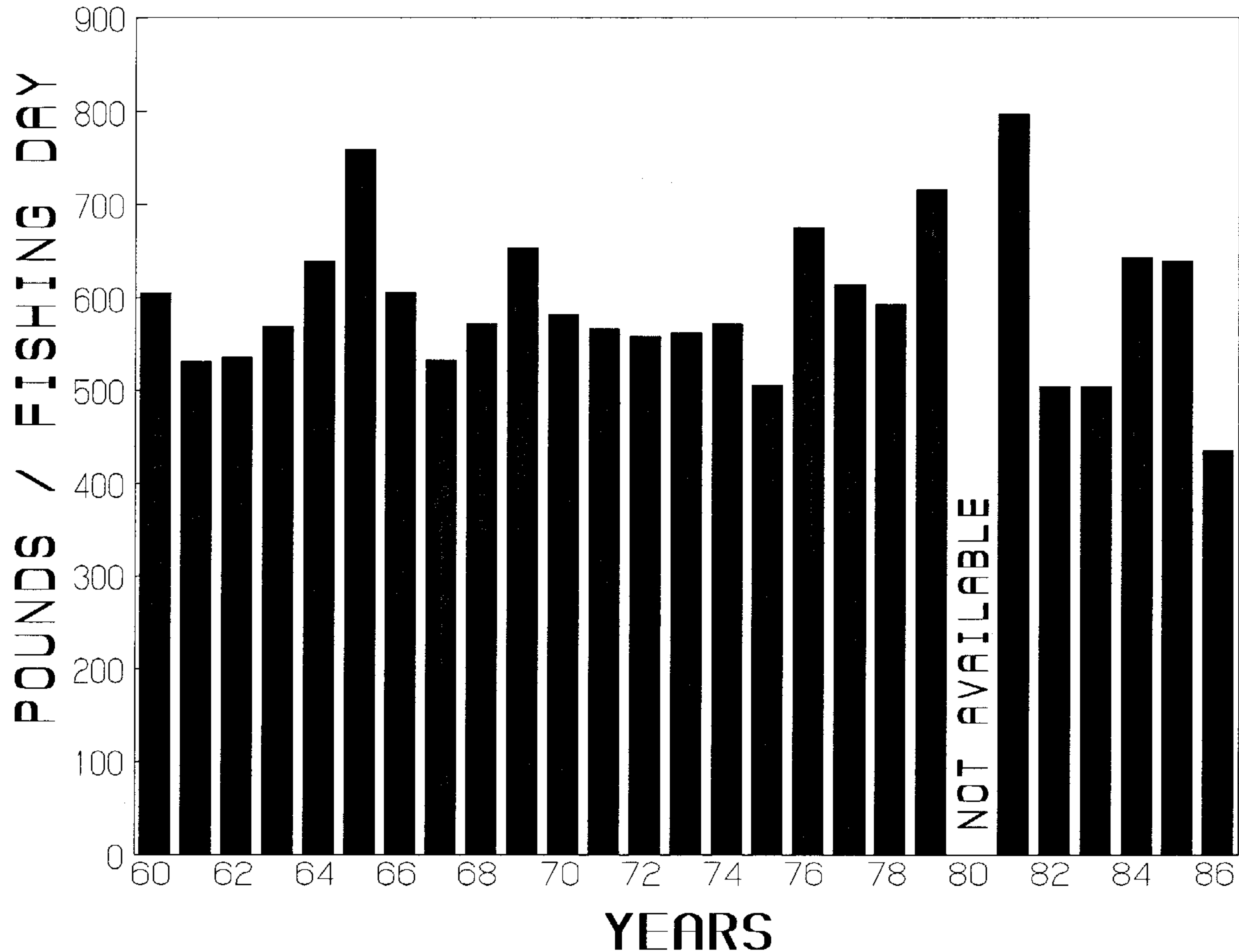


Figure 6. Catch per unit effort (CPUE) for biological years 1960 through 1986.

PINK SHRIMP TOTAL CPUE

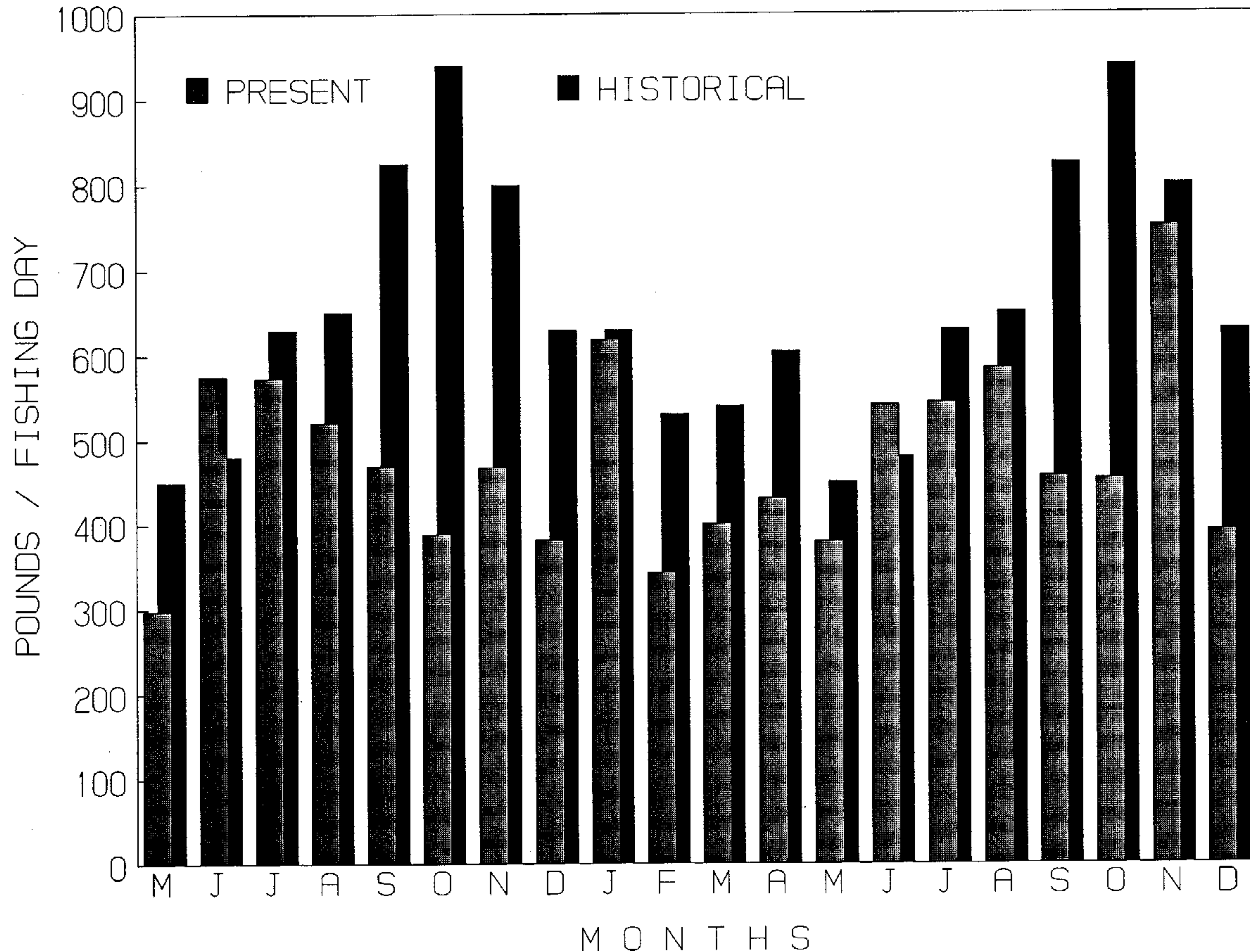


Figure 7. Average monthly historical CPUE values compared to the monthly CPUE values for May 1986 through December 1987 from the Tortugas grounds.

PRESENT / HISTORICAL RATIO

CPUE RATIO

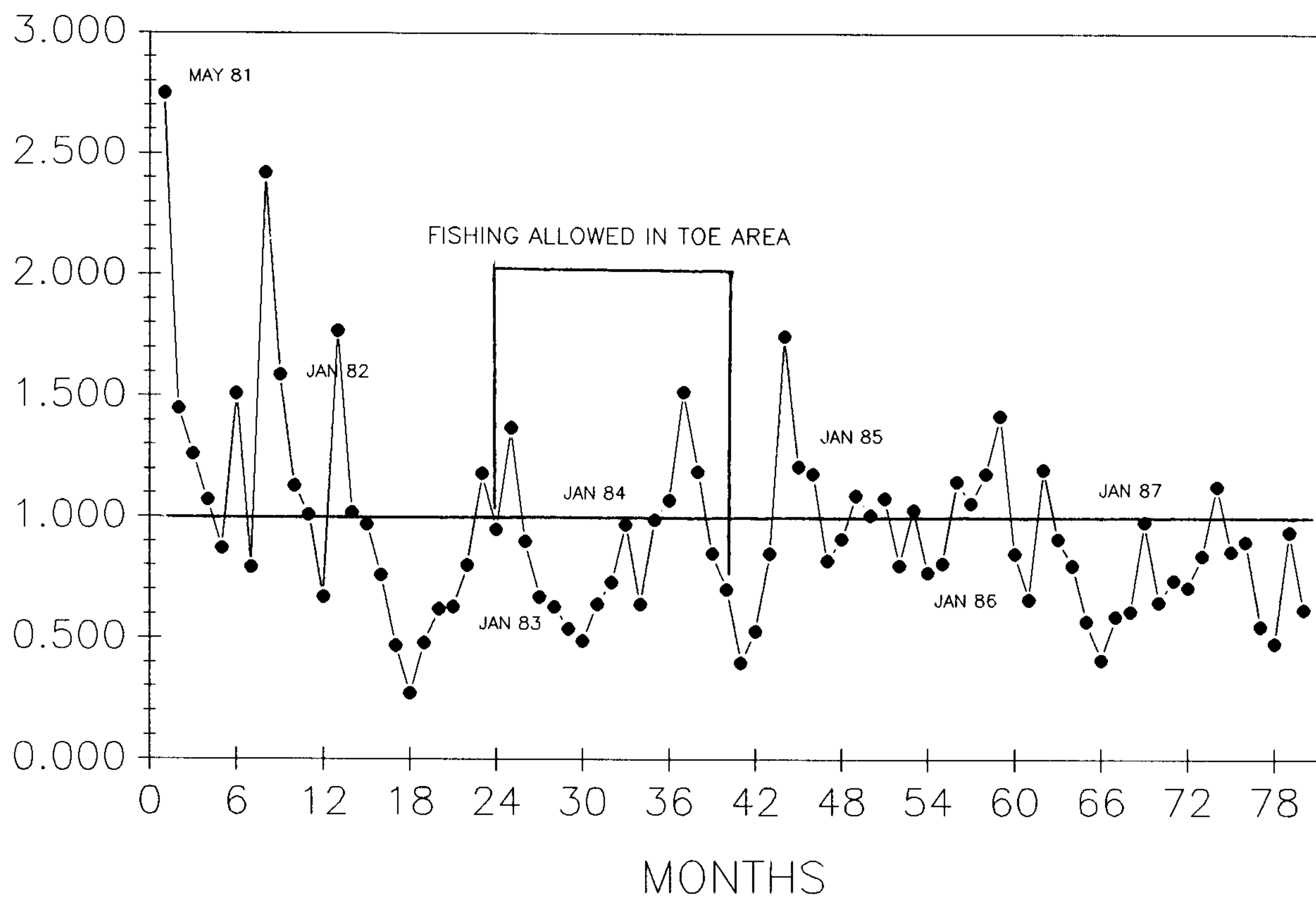


Figure 8. Ratios of monthly CPUE from May 1981 through December 1987 compared with monthly historical CPUE values (1960 through 1979).

TOTAL PINK SHRIMP RECRUITMENT

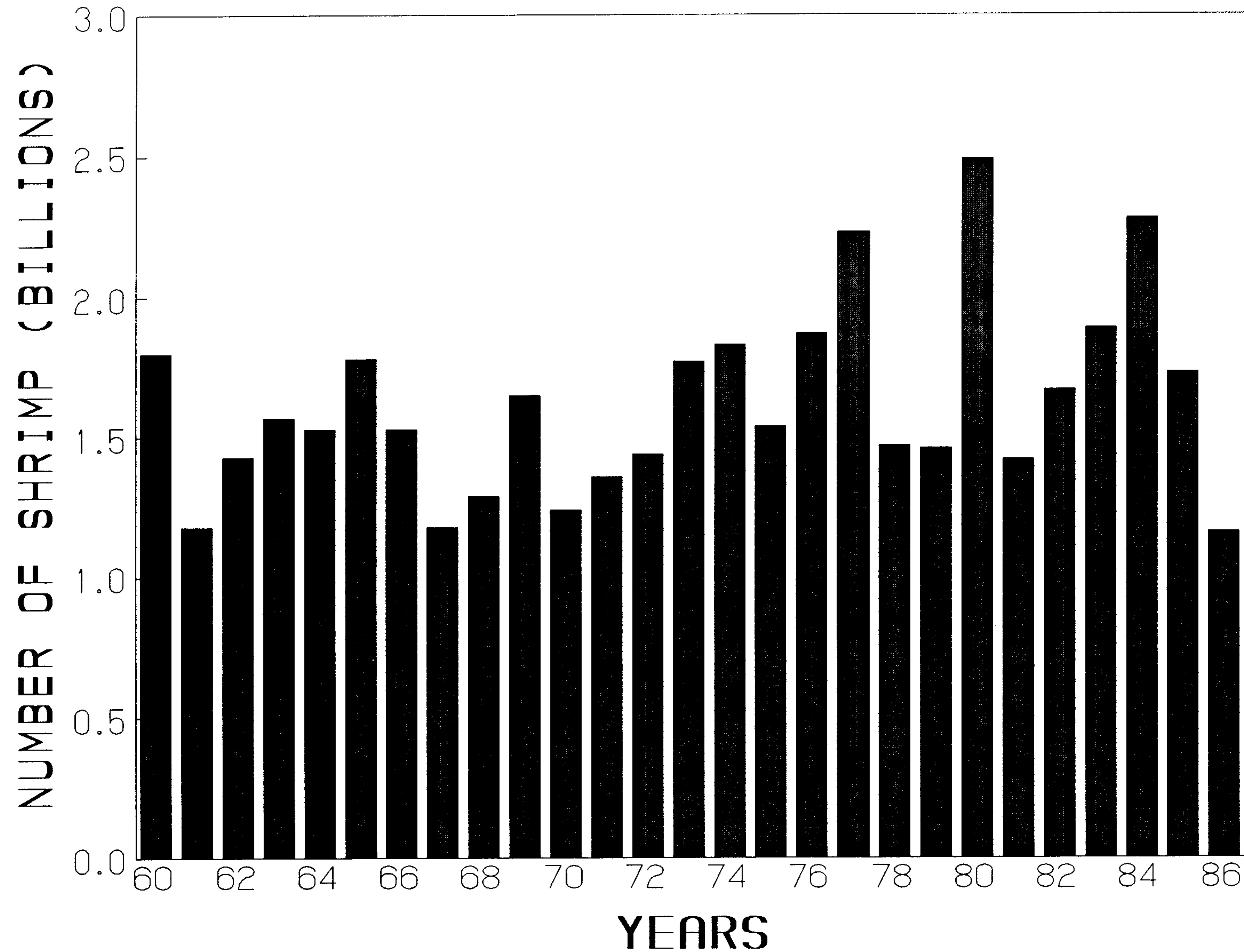


Figure 9. Total pink shrimp recruitment for the Gulf of Mexico from 1960 through 1986.

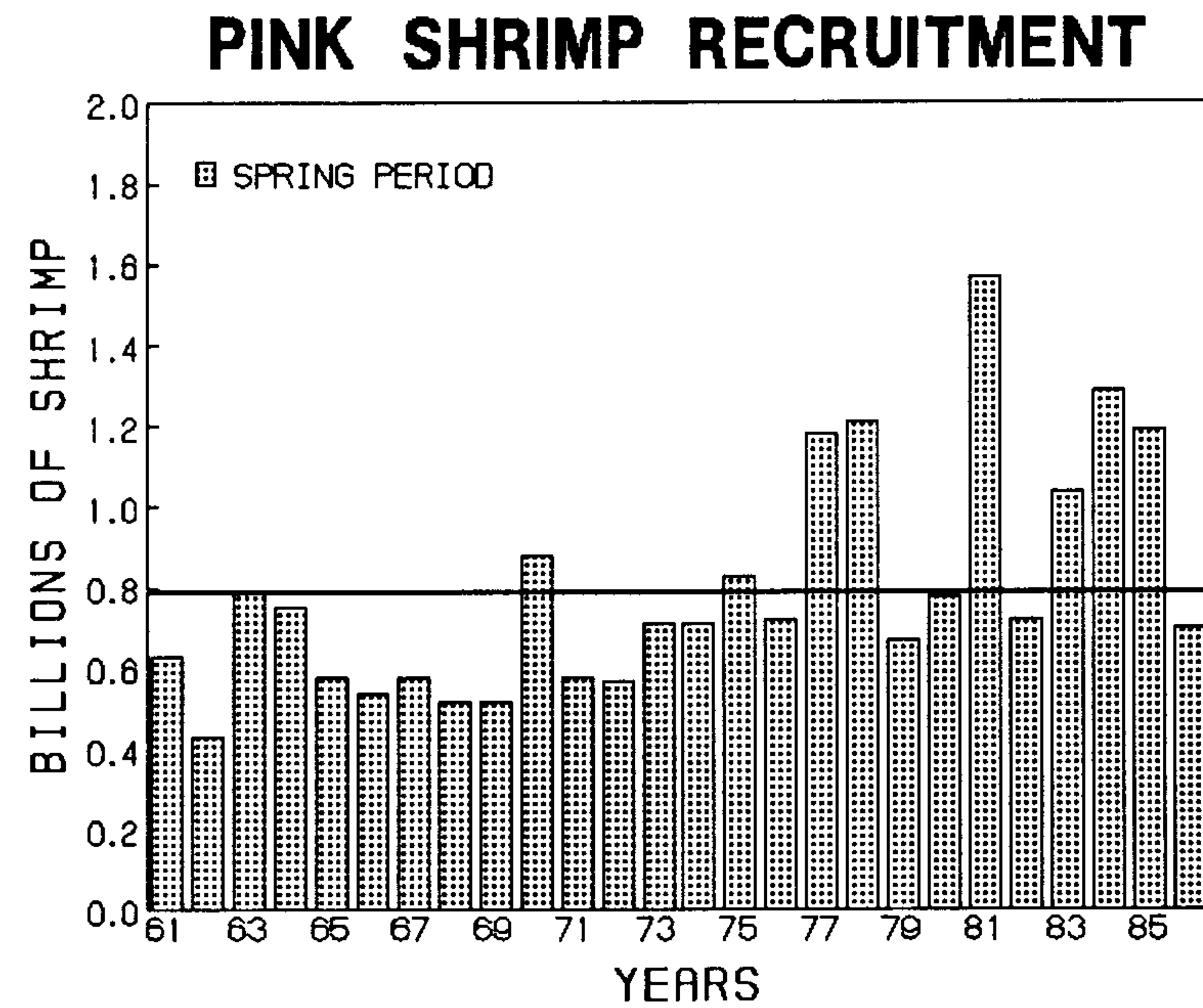
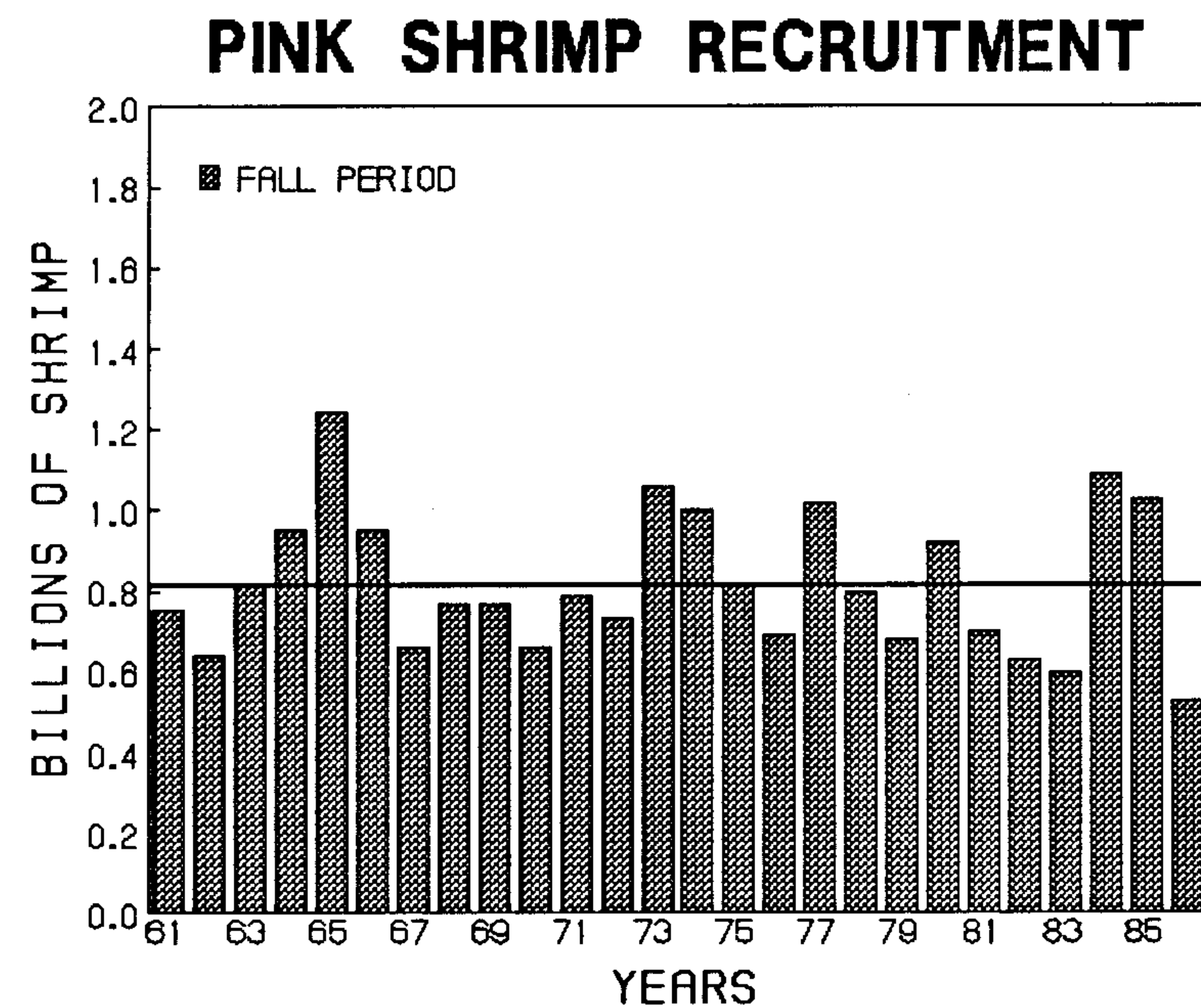


Figure 10. Seasonal trends in pink shrimp recruitment during the two recruitment periods (Fall and Spring).

PINK SHRIMP RECRUITMENT

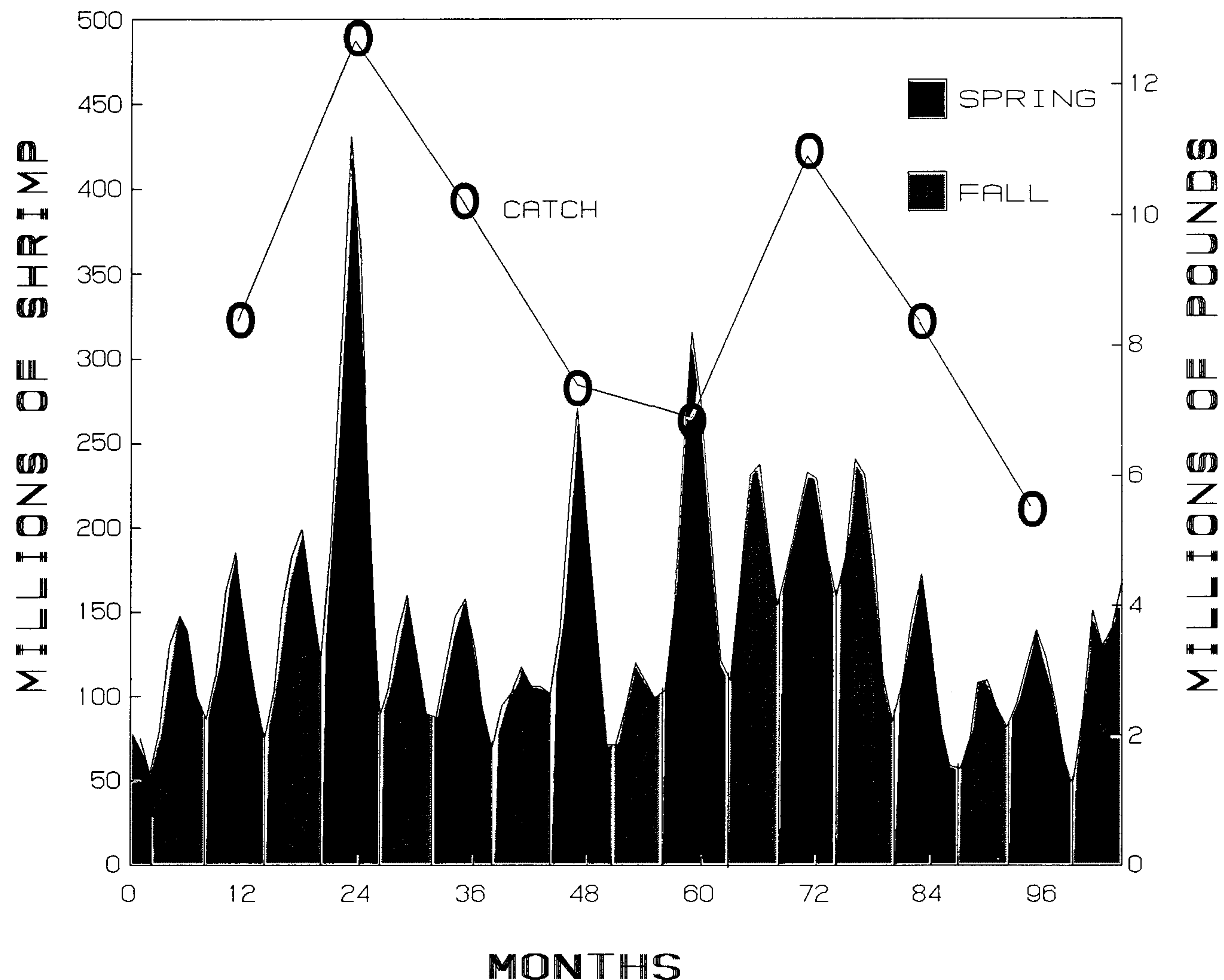


Figure 11. Comparison of seasonal trends in pink shrimp recruitment and annual catch from the Tortugas grounds. Recruitment period covers May 1979 through December 1987.

SIZE RATIO

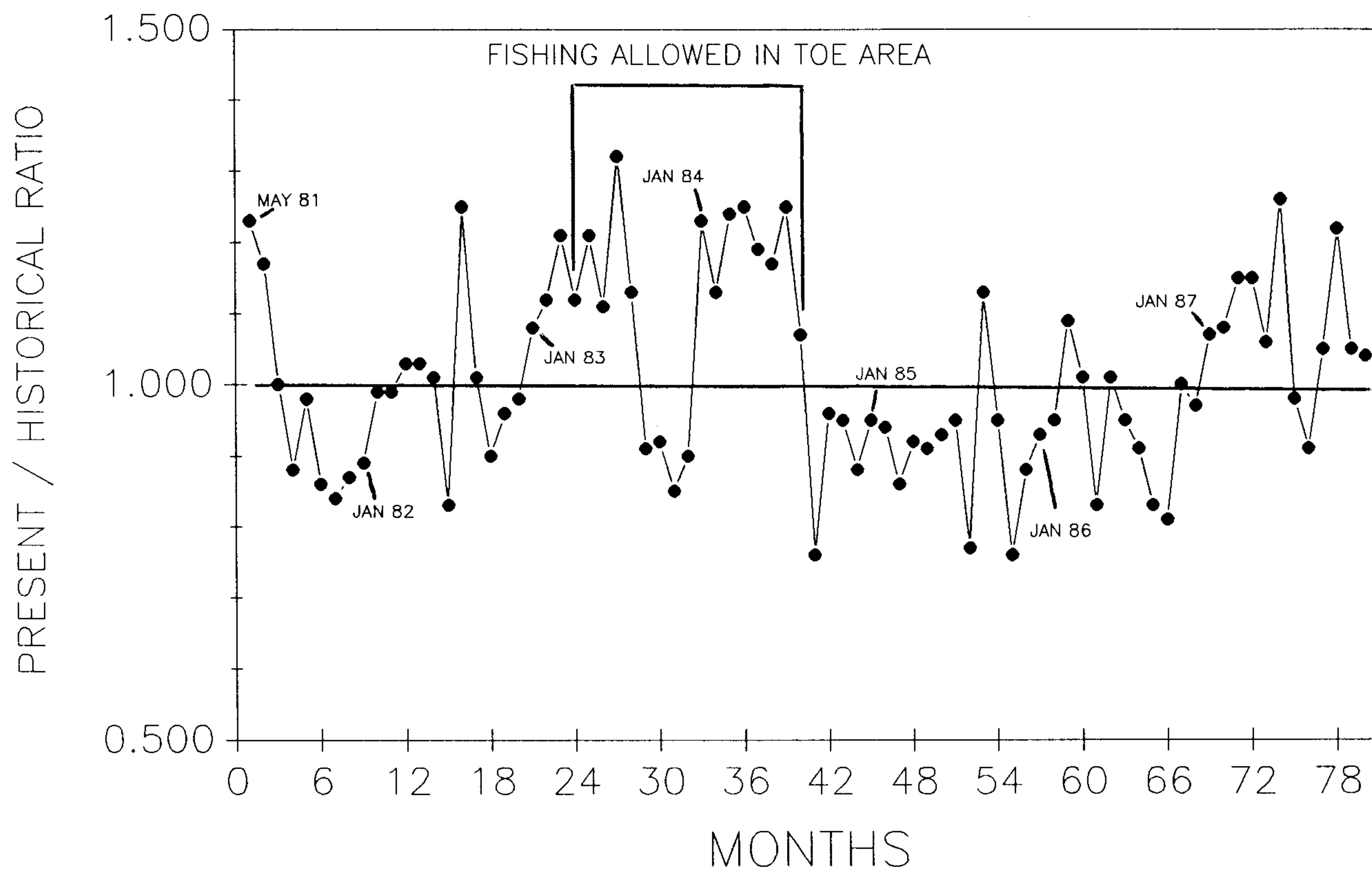


Figure 12. Ratio of monthly mean numbers of pink shrimp per pound from May 1981 through December 1987 to monthly historical mean numbers of pink shrimp per pound values (1960 through 1979).